Preliminary TOPEX/POSEIDON SLR and GPS Station Coordinate Calibration

by

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ABSTRACT

TOPEX/POSEIDON (T/P) is a joint altimetric mission of U.S. NASA and French CNES design launched August 10, 1992. There are a variety of tracking systems on T/P for both operational and precise orbit determination, but the T/I? tracking data selected for this study were satellite laser ranging (SLR) data and global positioning system (GPS) receiver data. Each of these tracking systems provides unique information for orbit determination of T/P relative to their respective coordinate reference frames. This paper presents the results of simultaneously processing SLR and GPS tracking data to produce a calibration of the differences between these two coordinate frames. The coordinate reference for SLR processing depends on the adopted station locations while the reference for GPS tracking depends on both the GPS space vehicle (SV) orbits and the locations of GPS ground receivers used for difference observable processing.

The seven parameter transformation between the SLR and GPS coordinate frames is determined by combining estimates from more than twenty data arcs which estimate the T/P orbit, spacecraft dynamical parameters, and measurement system parameters. Since the SLR tracking data for T/P is sparse, the SLR station locations are not adjusted during the calibration but are held fixed at their SSC(CSR)92L01 values (Ref. 1). Thus the SLR data ties T/P to the SLR coordinate frame, while the SLR and GPS data determine the T/P orbit which is used, in turn, to determine geometric ties between the SLR and GPS frames. There are, of course, other measurement system factors which influence the estimates of a SLR-GPS frame tie, including the effect of T/P orbit error and arc length, geometric ties between GPS and SLR phase centers (both ground based and on T/P spacecraft), and the level of fiducial processing used for GPS. Each of these effects are considered in the paper.

As a preliminary calibration, a twenty day data arc was chosen covering cycles 19 and 20 during late March, early April 1993. A cycle for T/P is one ground track repeat period 127 revolutions long (about ten days long), and the cycles have been numbered sequentially since entering the operational orbit on September 23, 1992. This arc was chosen since there is good GPS and SLR coverage, there is no anti-spoofing to degrade GPS performance, and the GPS SV constellation is free of solar occultations. Since other processing results have indicated there are residual modeling errors for solar pressure on the GPS SV'S, this last feature improves the SV orbit determination capability which in turn improves the T/P orbit estimates. The orbit accuracy is believed to be within 5 cm radial, rrns, and within 15 cm three-dimensional position, rms, based on internal consistency and comparison with T/P project precision orbits.

The paper describes the scheme to determine the preliminary station coordinate calibration and its sensitivity to various orbit and measurement related error sources. The basic technique is to process tracking data over one day arcs by first converging a GPS dynamic solution. A square root information filter was used for the one day data fits, and individual factorized information matrices for the frame tie parameters were extracted. The individual one-day frame tie information matrices were then combined to produce a global solution for the frame tie parameters.

The GPS processing uses implicit double differencing for calibrated phase and pseudo-range tracking from T/P and a network of fourteen ground receivers to simultaneously determine T/P and GPS SV orbits along with selected GPS ground station location estimation (i.e., a fiducial processing technique in which a subset of ground stations are held fixed, see e.g., Ref. 2). The sensitivity to GPS measurement system biases is determined by estimating a GPS phase center offset for T/P.

Sensitivity to the GPS phase center offset is tested by holding it at a fixed value when adding SLR data and comparing this result to that obtained by simultaneously estimating a SLR phase center offset. Testing the sensitivity/observability of the seven parameter transformation is performed by estimating a subset of the transformation (e.g., the three position offset parameters) and then comparing these to values obtained from the full seven parameter solution. The sensitivity of the combined estimate to our particular data set is determined by combining subsets of SRIF arrays from different arcs and comparing to individual arc solutions and the global solution.

For simultaneous processing of SLR and GPS tracking, tests were performed to select optimal relative data weights. The results of these tests are summarized in Table 1. Day-of-year 33, 1993, tracking from T/P cycle 14 was chosen for the tests, and fits were performed on each data type individually, for completely overlapping 24 hour arcs, and for non-overlapping 12 hour tires, The orbits from each of these fits were compared to a precision orbit determined from ten-days of SLR tracking covering the same time period. The resulting rms and mean orbit differences over the 24 hours of the test fit in radial (R), transverse (T), and normal (N) directions are shown in Table 1 for each case. The relative weights for the GPS and SLR data were chosen to make orbit differences from the individual fits to the ten day SLR fit about the same. The GPS phase data was weighted at two cm, the GPS pseudorange was weighted at 2 m, and the SLR data was weighted at about two cm (on average, since not all SLR tracking stations are equally weighted). The radial differences for the case with twelve hours of non-overlapping GPS and SLR data are plotted in Figure 1. The first twelve hours of the fit contains only GPS data while the second twelve hours of the fit contains only SLR data. Note that the once-per-rev signature evident in the plot shows little variation across the fit, indicating the two data types have appropriate relative weights.

REFERENCES:

1. IERS Technical Note#11, Central Bureau of IERS-Observatoire de Paris, June 1992, p 75.

2. Guinn, J. R. and P. J. Wolff, "TOPEX/Poseidon Operational Orbit Determination Results Using Global Positioning Satellites," Paper AAS 93-573 presented at the AAS/AIAA Astrodynamics Specialist Conference, Victoria, B. C., Canada, August 16-19, 1993.

TABLE 1.

TOPEX GPS/LASER Study

MIRAGE GPS & Laser Dynamic Orbits (DOY 033- Cycle 14)

CASE	Obs Residuals (cm) GPS / Laser	Orbit Differences (cm) RMS / Mean GPS R	GPS T	GPS N	LASER R	LASER T	LASER N
1) GPS Only	0.55 I --	--	--	--	4.1 /.01	18.0/ 4.1	13.9/ 0.1
2) Laser Only	--/ 12.1	4.1 /-.01	18.0/ -4.1	13.9 /-0.1	--	--	--
3) GPS(24hr) + Laser (24hr)	0.62 / 12.1	4.5 / -0.2	10.7/ -1.8	13.4/ 0.1	5.4 / -0.2	15.7/ 2.2	2.8/ -0.1
4) GPS(12hr) + Laser (12hr)*	0.59 / 12.1	4.5/-0.2	10.8/ -1.8	13.7/ 0.1	5.2/ 0.2	21.6 / 14.9	24.1 / 0.3
5) Case3 w/CM Estimation†	0.59/ 12.1	4.5/ -0.2	10.7 /-1.8	13.4 /0.1	5.4 / -0.2	15.7/ 2.2	2.8/ -0.1

*Relative Weights: GPS = 2cm, Laser= ~2cm

† frame Tie CM Estimates: X = 2.6cm, Y = 12.5 cm, Z = -10.3 cm

FIGURE 1.

GPS+LASER 12/12 (1cm GPS) vs SLR 10 day